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Diversity of Arthropods and Parasitic Nematodes Population in Intercropping Patterns of Robusta Coffee

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Abstract

Shade plants affect the microclimates around the plants which directly affect the population of arthropods, especially insects. Therefore, this research was needed to analyze the diversity and role composition of insects in Robusta coffee plantations based on different intensity of shade plants. Samplings of insects and parasitic nematodes were conducted in intercropping patterns of Robusta coffee namely mixed intercropping patterns, coffee-pepper intercropping patterns and coffee-banana intercropping patterns. In each intercropping pattern of Robusta coffee, samplings were conducted as much as ten plants using random sampling. Data analysis was done by calculating the Shannon-Wiener diversity index (H') and evenness index (E). The results showed that diversity index in all Robusta coffee intercropping patterns were < 3, indicating that the diversity of insects in all intercropping patterns was relatively. Insect diversity in coffee-pepper intercropping pattern is found higher than the one in either mixed intercropping pattern or coffee-banana intercropping patterns. Out of those intercropping patterns, insects from Formicidae family of Hymenoptera order was found to be the most dominant insects. The composition of insects in all of those three intercropping patterns has been mainly dominated by insects from the family of Formicidae and Hymenoptera order since they are natural enemy insects. *Pratylenchus coffeae* has been confirmed as the most dominant nematode species in the three Robusta coffee intercropping pattern. *P. coffeae* had the highest population average of 3279 in coffee-pepper intercropping pattern.

Keywords: Arthropoda, diversity, intercropping pattern, parasitic nematode, Robusta coffee

INTRODUCTION

Arthropods, especially insects, are organisms that dominate food network and food chain in almost all types of ecosystems. Expert state that insects are abundant in number, reaching up to 80% of organisms on earth. Waller *et al*. (2007) also reported that more than 850 insect species are associated with coffee plants around the world, while around 200 species or 23.5% are found in the Americas.

Some experts argue that ecosystems only consist of plants and pests. To improve farming productivity, all insects around the plants should be immediately controlled. Apart from the fact that some insects are not pests, some insects and organisms give positive benefits (insect parasitoid, predator, pollinator and decomposer of organic materials). This understanding has led many people to apply improper control measures such as improper use of pesticides which would lead to stronger resistance among the pests toward chemical

pesticides, resurgence, natural predators, and other benefical insects (Untung, 2006). This research has been supported by the results of a research conducted by Sulistyowati *et al*. (2002), which shows that intensive use of insecticides can disrupt the ecosystem of cocoa plant as it kills the natural predators, reducing the ability of the natural predators to control pest populations. The research also mentioned that without the use of pesticides in cocoa ecosystem, the composition of anthropod was dominated by predatory groups (47.48%), beneficial insects and neutral insects 44.47%. The composition of anthropods in cocoa ecosystem In the cacao ecosystem in which pesticides were used, the composition of arthropods was dominated by pest groups (76.19%) while parasitoid, predator, and beneficial insects groups took 0.87%; 5.78% and 17.16% respectively.

Shade plants play significant roles in the cultivation of coffee and cocoa plants. Shade plants affect the microclimates around the plants which directly affect the population of arthropods, especially insects. Rasiska (2017) explains that shade plants among coffee plants affect the diversity of insects. Coffee plants with Toona trees as shade plants around had low-moderate insect diversity index in which *Empoasca* sp. dominated the diversity. The number of insects found around coffee plant with white teak as shade trees showed moderate diversity index which was dominated by *Agromyzidae* families and *Empoasca* sp. Whilst, the use of pine tree as shade plants resulted in low to moderate diversity index with high number of *Empoasca* sp. and *Agromyzidae* families.

The diversity and abundance indices of arthropods in ecosystems are beneficial in applying integrated pest control (IPM). Based on the composition and diversity of insect species within food network of coffee plant ecosystems, it is expected that optimal pest control recommendations can be designed based on the basic principles of IPM. This research was conducted to analyze the diversity and role composition of insects in Robusta coffee plantations based on different intensity of shade plants.

MATERIAL AND METHODS

The study was conducted in the Robusta coffee plantation in Way Harong Village (S = 050 17,229'; E = 104045,764'; 258 m asl.) and Sinar Sekampung Village (S = 050 16,889'; E = 104044,677'; 296 m asl.) Air Naningan District, Tanggamus, Lampung. Identification of insect was conducted in Laboratory of Crop Protection, Indonesian Coffee and Cocoa Research Institute.

Samplings of insects and parasitic nematodes were conducted in intercropping patterns of Robusta coffee namely mixed intercropping patterns, coffee-pepper intercropping patterns and coffee-banana intercropping patterns. In each intercropping pattern of Robusta coffee, samplings were conducted as much as ten plants using random sampling. Observation of insect species on the Robusta coffee was carried out by spraying insecticides with high knockdown effect, namely synthetic pyrethroid insecticides with active ingredient namely deltamethrin with a concentration of 0.1%. Spraying was carried out on each sample tree, then the bottom of the tree is spread over plastic sheets to collected falling insects. Handpicking with forceps was done for insect, insect collected were kept in a film bottle containing alcohol 70%. Taxonomic classification of insects is done by identifying key orders and families using Kalshoven (1981); Borror *et al*. (1992) and Triplehorn & Johnson (2005).

Data analysis was done by calculating the Shannon-Wiener diversity index (H') and evenness index (E). H value for knowing insect diversity and evenness values. The Shannon-Wiener index can be calculated using

the following formula (Shannon & Weaver, 1964 cit. Dinesh *et al*., 2018):

$$H' = \sum_{i=1}^{S} (pi)(\ln pi)$$

Pi : Σ*ni/N*
H' : Shannon-Wiener index
Pi : Proportion of total sample represented by species *i*
Devide no. of individuals of species *i* by total number of samples
ni : Number of individuals of species *i* in the sample
N : Total number of individuals

The criteria for the value of diversity index (H') indicate that if H' > 3: high species diversity and ecosystem stability, high productivity and resistance to ecological pressure. 1 < H' < 3: species diversity and ecological pressure are moderate, productivity is sufficient, and ecosystem conditions are quite balanced. If H' < 1 : low species diversity and productivity are indicative of heavy pressure and unstable ecosystems.

The evenness index is calculated by using the formula (Olawusi-Peter & Ajibare, 2014):

$$E = \frac{H'}{\ln(S)}$$

E : Evenness index
H': Shannon-Wiener diversity index
S : Number of observed species

Evenness values range from 0-1. The value of E which approaches the number 0 (zero) indicates that a species has become dominant in the community. If the value of E approaches 1 (one), it means that all species have similar levels of similarity (Ludwig & Reynold, 1988 *cit.* Haneda, 2013; Apriliyanto & Sarno, 2018).

RESULTS AND DISCUSSION

In mixed intercropping patterns, there are 14 plants that function as shade and intercropping plants besides coffee including *Archidendron pauciflorum*, *Paraserianthes falcataria*, *Piper nigrum*, *gliricidia sepium*, *Musa* spp., *Erythrina* spp., *Ceiba pentandra*, *Magnolia champaca*, *Lagerstroemia* spp., *Durio zibetinus*, *Leucaena* spp., *Cocos nucifera*, *Tectona grandis*, *Syzigium aromaticum*. In the intercropping pattern of coffee-pepper, there are four namely *Archidendron pauciflorum*, *gliricidia sepium*, *Paraserianthes falcataria* and *Piper nigrum*; while in the intercropping pattern of coffee-banana was only found one shade plant namely *Musa* spp.

In general, the abundance and diversity of insects is determined by environmental factors. Insects has a suitability for certain environments. Based on the observation of microclimate, coffee plantations with mixed intercropping patterns has a temperature of 33^{O}C with a humidity 55% and light intensity of 300 lux; in intercropping pattern of coffee-pepper has a temperature of 36^{O}C with a humidity 47% and light intensity 800 lux; in intercropping pattern of coffee-banana have a temperature 33.5^{O}C with humidity 51.5% and light intensity 750 lux. The temperature and light intensity in the mixed intercropping pattern are lower than the intercropping pattern of coffee-pepper and coffee-banana, while the humidity in the mixed intercropping pattern is higher than the intercropping of coffee-pepper and coffee-banana. Different environmental conditions cause the abundance of insects in the three intercropping patterns to be different. According to Haneda (2013), temperature affects insect activity, development, geographical and local spread. Humidity influences evaporation of insect body fluids and selection of suitable habitat. Light intensity also affects the presence of insects in field. Unlike nocturnal insects, diurnal insects will use sunlight for activity (Aditama & Kurniawan, 2013).

The numbers of individuals in each insect order and family in different intercropping patterns are shown in Table 1. The abundance index of individuals in mixed intercropping pattern was found higher than the one found in coffee-pepper intercropping pattern and coffee-banana intercropping pattern. Insects

from Hymenoptera order obtained the highest abundance index of individual (92.01%); while the lowest abundance index was found in Neuroptera order (0.02%).

There were a total of 4980 insects from 14 orders and 24 families found in the observations on mixed intercropping patterns. Meanwhile, there were a total of 3064 insects indicudals from 11 orders and 20 families in coffee-pepper intercropping patterns and a total of 3698 insect individuals from 12 orders and 23 families in coffee-banana intercropping pattern (Table 2).

Habitat factors were assumed to play certain role in those different findings as cropping pattern with mixed intercropping patterns were found in plants that function as shade and intercropping plants which number and type were found higher in coffee-pepper intercropping patterns and coffee-banana intercropping pattern. This findings support the results of research conducted by Haneda (2013), which shows that the abundance of plant species affects the composition and abundance of insects in several different types of habitats.

Table 1. Number of individuals in order and family of insects found in different intercropping patterns of Robusta coffee

Order	Family	Individual number		
		Intercropping patterns of Robusta coffee		
		Mixed	Coffee-pepper	Coffee-banana
Araneae	Araneae1	83	36	40
Blattodea	Blattidae	30	4	9
Coleoptera	Byrrhidae	1	2	1
	Byturidae	3	0	6
	Carabidae	0	4	11
	Coccinellidae	4	2	1
	Scolytidae	1	0	0
	Tenebrionidae	38	16	142
Collembola	Collembola1	23	16	106
Dermaptera	Forficulidae	3	6	0
Diptera	Culicidae	5	1	1
	Drosophilidae	11	1	14
	Sinulidae	3	0	0
Hemiptera	Alydidae	1	0	10
	Cicadidae	21	0	6
	Pyrrhocoridae	2	0	0
Hymenoptera	Formicidae1	4633	1447	3185
	Formicidae2	15	3	15
	Formicidae3	0	1482	0
	Formicidae4	0	0	24
	Ichneumonidae	4	24	12
Lepidoptera	Geometridae	17	2	6
	Gracillariidae	0	1	0
	Hepialidae	3	0	0
	Pyralidae	29	7	42
	Saturniidae	0	2	14
Orthoptera	Acrididae	43	7	23
	Gryllidae	0	0	8
	Mantidae	1	0	0
Neuroptera	Myrmeleontidae	0	1	1
Thysanoptera	Thripidae	6	0	21
Total		4980	3064	3698

Table 2. The diversity value of the Shannon-Wiener index in different intercropping patterns of Robusta coffee

Intercropping patterns	Number of			H'	E
	Order	Family	Individual		
Mixed	14	24	4980	0.43	0.13
Coffee-pepper	11	20	3064	0.94	0.32
Coffee-banana	12	23	3698	0.73	0.23

Notes: H = Diversity value of Shannon-Wiener index
E = Evenness value.

According to Untung (2006), a diverse community tends to have higher diversity. Despite other factors that might affect the diversity, the number of species in the community remains the simplest measure. Diverse communities have more species than less diverse communities. There are several factors that influence diversity including the existence of agro-ecosystems that often experience sudden changes in microclimate as a result of human activities such as tillage, fertilization, irrigation, weeding, burning, pruning, use of chemical substances and other cultivation activities.

Shannon-Wiener index is a basic and fundamental indicator of species diversity and abundance (Dinesh *et al*., 2018). The diversity index in all Robusta coffee intercropping patterns were < 3, indicating that the diversity of insects in all intercropping patterns was relatively low. This condition reflected the unstable condition of the ecosystem. Table 2 shows that insects foudn in three different cropping patterns had different species diversity indices. Mixed intercropping pattern obtained the highest number of individuals, while the highest insect diversity index was found in coffee-pepper intercropping pattern (0.94). In the mixed intercropping and coffee-banana intercropping patterns, the insect diversity values were 0.43 and 0.73 respectively. In mixed intercropping patterns, the high number of individuals was not equally followed by high Shannon-Wiener (H') diversity index. This occurred because there was a dominant insect species from Formicidae family of Hymenoptera order. Ludwig & Reynold (1988) *cit*. Haneda (2013) explained that maximum diversity index (H') can be obtained if all species (the total number of individuals in a community) are represented by the same number of individuals. Diversity of insect species is influenced by several factors including the quality and quantity of food, number of suitable host plants, density and composition of host plants and the age of host plants.

Evenness value (E) in mixed intercropping pattern, coffee-pepper intercropping and coffee-banana intercropping were 0.13; 0.32 and 0.23 respectively, which indices were closer to zero. This condition indicateed the presence of one type of dominant insect from Formicidae family of the order Hymenoptera. Evenness value shows the distribution pattern of certain species in certain community. Greater evenness value shows more balanced distribution pattern of certain species in a community and vice versa.

As a component of biodiversity, insects holds important role in the food chain as herbivores, carnivores, and detritivores (Rizali *et al*., 2002). Ecologically, herbivorous insects act the controller of abundant number of plants. For example, herbivorous insects can be employed to control parasitic plants or weeds. On the other hand, carnivorous insects or natural enemies will control the abundance of pest or prey (Putra, 2010).

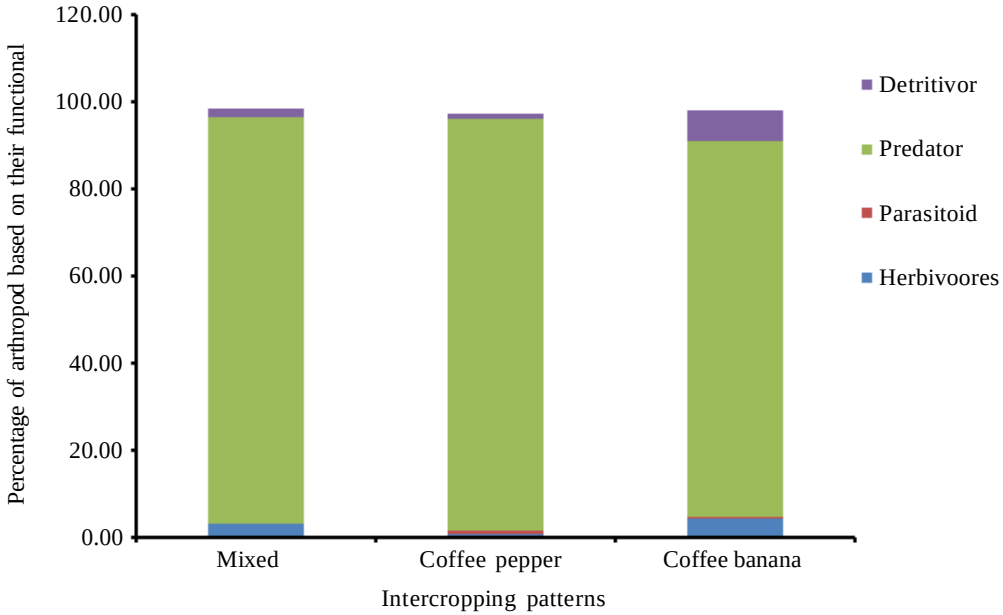

Figure 1. Percentage of insects based on their functional in different intercropping patterns of Robusta coffee

The total individual of insects identified in this research was 11.742 identified individuals where 2.93% of which were herbivorous insects, 95% natural enemy insects (parasitoid and predator), 1.79% detritivorous insects in mixed intercropping patterns; insect composition in coffee-peeper intercropping of 0.73% herbivorous, 95.12% natural enemies and 1.14% detritivorous insects. Insect composition in coffee-banana intercropping pattern included 4.02% herbivorous insects, 86.90% natural enemy insects and 6.79% detritivorous insects (Figure 1). Of all intercropping patterns, herbivorous insects consist of species from Coleoptera, Diptera, Hemiptera, Lepidoptera, Orthoptera and Thysanoptera. The family of the order Hymenoptera were rather found as natural enemy insects, both as parasitoid and predator. Predator insects were predominantly from Formicidae family of Hymenoptera order. Based on the results of the observations, most of Formicidae insects found were black ants (*Dolichoderus thoraxicus*) and weaver ants. According to Longino (2006), the habitat of insects the family Formicidae is highly abundant and varied throughout tropical areas and many of which are found on the soil up to the end of the tree. Black ants have been widely employed as natural enemies, especially in cocoa plants as the abundant black ant population in cocoa plantations can reduce the percentage of fruit borer attacks in cocoa in Malaysia and Indonesia (Sulistyowati, 2015). Carnivorous insects such as weaver ants (Formicidae : Hymenoptera) have also been reported as predators of many types of pests and aggressive warriors ants prevent plants from pest attack as they are powerful in protecting their area (Putra, 2010). Way & Khoo (1992) stated that weaver ants (*Oecophylla smaragdina*) are natural enemies of 16 pest species in plantation crops such as cocoa, coconut, oil palm, mahogany, oranges, etc. The use of proper technology that suits the condition on the field will increase their potential as natural enemies (Van Mele, 2008).

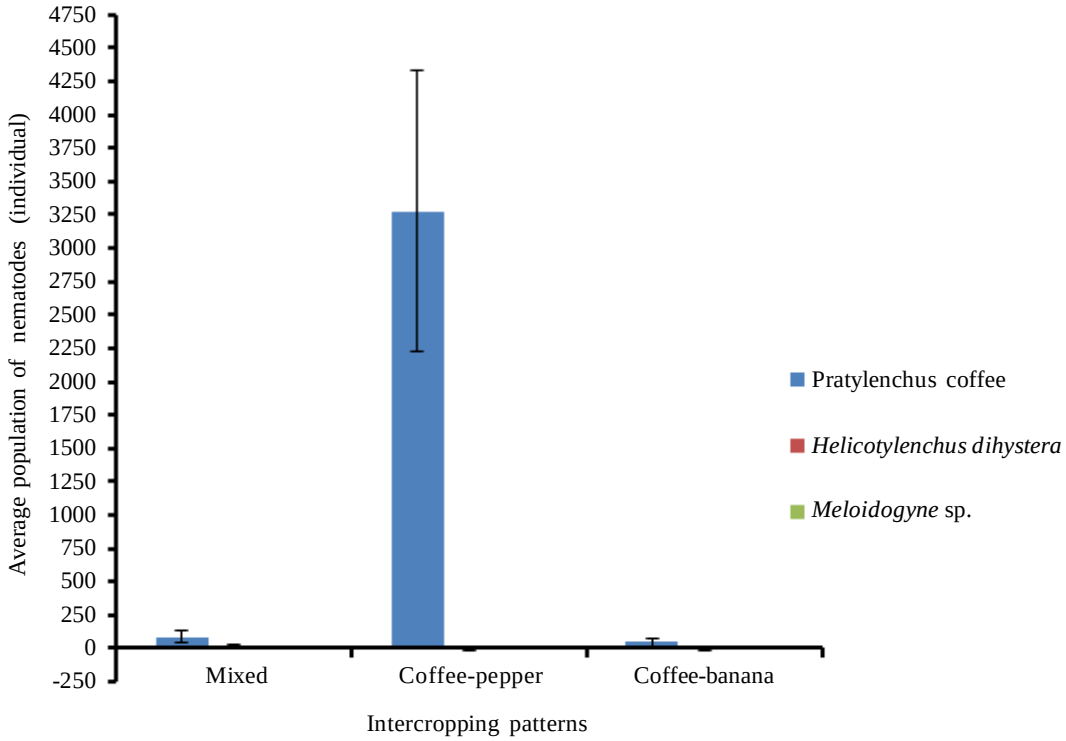

Figure 2. Number of parasitic nematodes in different intercropping patterns of Robusta coffee

Insects from the Order of Coleoptera (family of Tenebrionidae) and Collembola have been identified as detritivorous insects and were found in all three Robusta coffee intercropping patterns. Detritivor beetles such as Tenebrionidae live in habitats that have adequate amount of organic substances (Susilo *et al*., 2009). According to Keilhorn *et al.* (1999), the presence of organic materials creases the number of soil beetles to 200% even higher. In the food chain cycle, Collembola also acts as a decomposition agent of organic materials or detrivor and litter decomposition agent (Rohyani, 2012). Besides Collbeola was found on the surface of soils with high contents of organic materials or litter, Collembola were also found on fresh leaves (Ganjari, 2012).

The results of this research showed that parasitic nematodes were found, namely *Pratylenchus coffeae, Helicotylenchus dihystera* and *Meloidogyne* sp. The most dominant nematode species in the three Robusta coffee intercropping patterns was *P. coffeae*. The population of *P. coffeae* was at the highest level in coffee-pepper intercropping patterns reaching 3279 individuals. *P. coffeae* is one of the most destructive species of nematodes in coffee plants; *P. coffeae* has been found in almost all major coffee production sites in Indonesia including North Sumatra, Lampung, Central Java, East Java, Bali, South Sulawesi and East Nusa Tenggara. In addition, *Meloidogyne* sp. was also reported as one of coffee plant disrupting organisms and its population in coffee plants is considered very limited (Wiryadiputra, 2016). In this resaerch, *Meloidogyne* sp. was found in all coffee intercropping patterns both in mixed intercropping patterns, coffee-pepper intercropping and coffee-banana intercropping;

of 3 individuals, 3 individuals and 7 individuals resepctively. In mixed intercropping and coffee-peper intercropping pattern, some plants including pepper plants (*P. nigrum*) function as shade plants and intercropping plants. Whereas, Robusta coffee planting pattern using coffee-banana intercropping method, other shade plants such as banana plants which is one of the host plant of *Meloidogyne* sp. parasitic nematodes. According to Indriyati (2017), nematodes of the Meloidogyne Genus are the most destructive nematodes that might cause major problems of jaundice in plants which damage can reach up to 32%.

The spread of nematodes is strongly influenced by macro and micro climates of certain area. The absence of host plant in moist soil, *P. coffeae* is able to survive for 8 months. In the dry season, the population of *P. coffeae* drops dramatically due to inability to withstand temperatures above 38^{O}C besides nematodes are sensitive to low soil moisture, ultra violet rays and sunlight. In the rainy season, nematodes population will increase at rapid rate along with increases in root growth activity. Apart from the influence of climate, as alternative hosts, shade plants can also affect the development of nematode populations. More than 200 species of plants have been reported to host *P. coffeae*. Shade plants such as Gliricidia are good hosts for *P. coffeae* (Pradana *et al*., 2016; Wiryadiputra, 2016).

CONCLUSIONS

Insect diversity in coffee-pepper intercropping pattern is found higher than the one in either mixed intercropping pattern or coffee-banana intercropping patterns. Out of those intercropping patterns, insects from Formicidae family of Hymenoptera order was found to be the most dominant insects. The composition of insects in all of those three intercropping patterns has been mainly dominated by insects from the family of Formicidae and Hymenoptera order since they are natural enemies insects. *P. coffeae* has been confirmed as the most dominant nematode species in the three Robusta coffee intercropping pattern. *P. coffeae* had the highest population average of 3279 in coffee-pepper intercropping.

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